Design modification of conventional wheat straw chopper

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Abstract: Agriculture has straight and indirect contribution to boost the economy of Pakistan.wheat and paddy are among the major rotational crops of Pakistan. The straw management in combine harvested in wheat fields is a major problem. In the past the residual wheat straw in convectional harvesting was burnt in the field which resulted lossesof 80% of Nitrogen, 25% P, 21% K and 4% to 60% S.To overcome this problem, locally available wheat straw chopper is used for cutting and collecting the wheat straw left behind the combine harvesters. These locally developedwheat straw choppers are heavy in weight having lowermachine efficiency. A wheat straw chopper has beenmodified using locally available materials making it light weight and more efficient. The performance evaluation of wheat straw chopper has been carried out in the field and further improvements have been incorporated to increase its field efficiency. The modified wheat straw chopper has been tested for its performance at Chakra Farms of the University of Agriculture, Faisalabad during the wheat harvesting season. The experiment was consisted of factorial completely randomized design. Three wheat varieties V1 (Sehar-2006), V2 (Lasani) and V3 (Faisalabad-2008) were selected in which modified wheat straw chopper was operated at two different tractor forward speeds S1 (1.77 km/h) and S2(2.42 km/h) and at two different levels of moisture contents M1(moisture at the same day of combining), M2(moisture after one day of combining). Results showed that wheat straw yield (kg ha-1) for V1, V2 and V3 was found to be 1425, 1118 and 1179 kg/ha respectively. Effect of moisture on wheat straw yield (kg/ha) was found to be significant, and higher wheat straw yield (kg/ha) was found to be at moisture content level M1.The wheat straw yield and efficiency of the wheat straw chopper was found to be higher at S1(1.77 km/h) which is for wheat variety V1 and 67.96% respectively.The average fuel consumption was found to be 9.3 L/ha.Breakeven point of the wheat straw chopper was occurred at 225 hours of use.

Keywords: Wheat variety, wheat straw chopper, straw yield, field efficiency

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1 Introduction

Pakistan is a developing country of South Asia.The entire geographical area of the country is 79.6 million hectares. Regarding 80% of total 23.5 million hectares cultivated area is irrigated.The cultivable lands provide 8.9 million hectares for wheat crop production. The development rate has considerably increased from11.6 million hectares in 1947 to 22.6 million hectares for the year 1997. Agriculture contributes almost 21.2% of Gross Domestic Product (GDP) and almost 43% of the country's work or labor force is employed in this sector. Agriculture is still the major sector of country's GDP (Anonymous, 2005-2006).

Wheat is one of the most important crops grown in the world and its annual production is about 650 million tons per year. World's production of wheat in the year 2010 was about 651 million tons, making it the third very significant cereal crop followed by maize (844 million tons) and rice (672 million tons).Wheat has been important staple food in Europe, Western Asia and North Africa. During the previous four decades the wheat crop has undergone historic changes (Baloch, 1994).

Biomass burning has induced worldwide concerns in the last few decades for its harmful effects on human physical condition and worldwide environment via releasing unusual particles and environment pollutants (Fang et al. 1999).Biomass burning is much common

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practice for farming leftoverresidue disposal which is a starting place of environmental pollutants (Jenkin et al. 1996; Korenageet al.,2001).Major pollutants released are CO, hydrocarbon and minor extent of SO_2.In spite of these pollutants there is an emission of volatile polycyclic aromatic hydrocarbons and organic pollutants. Many of these pollutants contain carcinogenic properties to the human being (Amagai et al., 1999; Liu et al.,2001;Ohura et al.,2004).

Wheat is grown on 8.5 million hectare area of the country. In the past traditional methods (manual or animal drawn reapers) were used for harvesting of wheat, however with the increasing trend of mechanization, combine harvester are being used to harvest the wheat crop. The combine harvester collect grains and throw wheat straw on the rear side of the combine in the field. Most of this wheat straw is normally burnt in the field while rest is used to feed the animals. Burning of wheat straw results losses of 80% Nitrogen (N), 25% Phosphors (P), 21% Potassium (K) and 4% to 60% Sulphur (S).Wheat straw is a major residual resource.However, the effective collections of this straw can increase its utilization factor in the form of animal feed, for paper industry or as a biomass resource for burning in biomass boilers for power production.Wheat straw is a very popular, major and important feed for the animals. Generally stacks coated with dried mud are made for chopped wheat straw and straw can be stored in these types of mud stacks for longer period of time. This type of wheat straw can effectively be used for urea straw treatment. Urea treatment enhances the intake and nutrient density, so treated wheat straw can form a superior ingredient of portion for a particular nutrient mass (Ali and Mallorie, 1987).

Locally available convectional wheat straw chopper are being used for collection of wheat straw in the country. However, the poor design of existing wheat straw choppers result in lower machine efficiency and higher fuel consumption due to its heavier weight as complained by the farmers.Therefore, farmers prefer to burn this wheat straw in the field due to higher fuel consumption of the conventional wheat straw chopper.

Keeping in view the above factors like burning of wheat straw and to overcome the disposal problem of wheat straw, higher fuel consumption and lower machine efficiency, this study has been carried out to modifylocallyavailablewheat straw chopperin the Department of Farm Machinery andPower, University of Agriculture, Faisalabad and to evaluate the performance of the modified wheat straw chopper in the field.

2 Materials and methods

A tractor mountedwheat straw chopper was modifiedusing the facilities inthe Department of Farm Machinery and Power,Faculty of Agricultural Engineering andTechnology, University of Agriculture, Faisalabad. This redesigned wheat straw chopper was tested for its field performance at fields of Chakra Farms ofthe University of Agriculture, Faisalabad. The data for wheat straw yield(kg/ha), efficiency of wheat straw chopper (%), straw size (m) and fuel consumption (L/ha) were collected in the combine harvested fields for two different levels of tractor forward speeds, three varieties of wheat and two different moisture levels.

2.1 Brief description of machine

The wheat straw chopper is a trailed machine towed behind a tractor during transportation and power is supplied through PTO shaft during its field operation. For wheat straw collection, a trolley is hooked behind the machine. The tractor pulls and provides power to wheat straw chopper and trolley.

2.2 Modifications in convectional wheat straw chopper

The modification was done in the conventional wheat straw chopper keeping in view the following points 1) To enhance the efficiency of the wheat straw chopper 2) To reduce the weight of the wheat straw chopper 3) Toreduce the power requirements 4) To reduce the size of the machine.

2.2.1 Reel

The reel of the modified wheat straw chopper (Figure 1) was made with cast iron. The necessary modifications were carried out and the comparisons of overall specifications of the existing/conventional and modified reel of the wheat straw chopper are shown in Table 1.

Table 1 Specifications of convectional and modified reel of wheat straw chopper

Parameters	Convectional wheat straw chopper	Modified wheat straw chopper
Length/m	2.13	2.07
No. of central pipe	1	1
No. of fingers on each pipe	20	12

2.2.2 Auger

The auger of the modified wheat straw chopper (Figure 2) was made with cast iron and the fingers were made with mild steel to increase their strength. The necessary modifications have been incorporated and the comparison of overall specification of the conventional and modified auger is shown in Table 2.

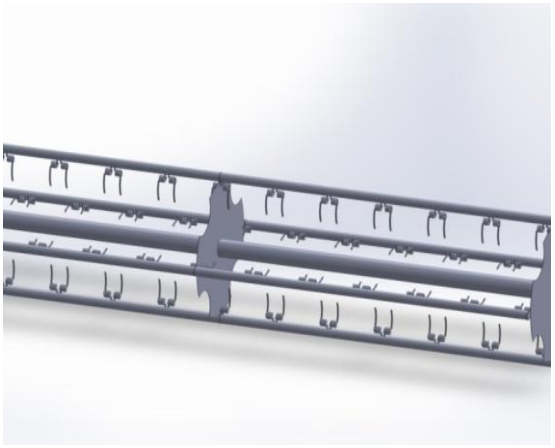


Figure 1 Modified reel of the wheat straw chopper

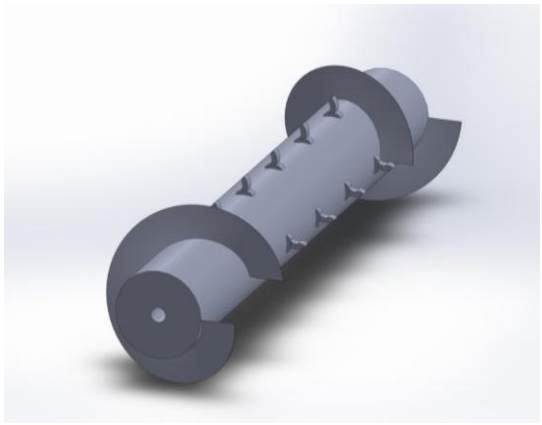


Figure2 Modified auger of the wheat straw chopper

Table2 Specifications of convectional and modified auger of wheat straw chopper

Parameters	Convectional wheat straw chopper	Modified wheat straw chopper
Length/m	2	2.16
Diameter/m	0.3175	0.3048
No. of fingers	26	20

2.2.3 Chopping drum

The chopping drum of the modified wheat straw chopper (Figure 3) was made of cast iron and cutters were made with mild steel. The overall specifications of the modified chopping drum are shown in Table 3.

Table 3 Specifications of convectional and modified chopping drum of chopper

Parameters	Convectional wheat straw chopper	Modified wheat straw chopper
Length/m	1.38	1.30
Diameter/m	0.483	0.534
No. of cutters	217	171

2.2.4 Fly wheel

The fly wheel of the wheat straw chopper was made with cast iron having diameter of 56cm. There are two fly wheels of the wheat straw chopper whose diameter was 56 and 53cm respectively. This fly wheel of the modified wheat straw chopper reduces the size and weight of the wheat straw chopper(Figure 4).

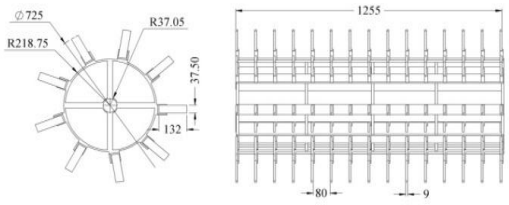


Figure 3 Modified chopping drum of chopper

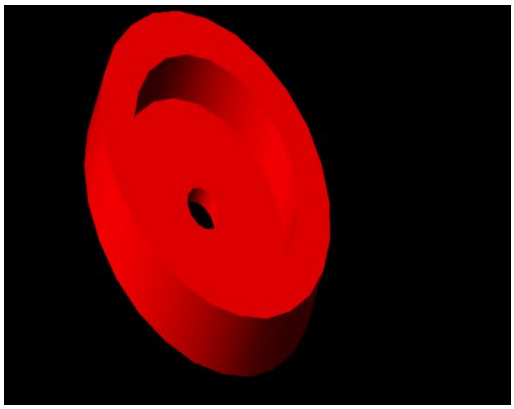


Figure 4 Modified fly wheel of the chopper

2.3Field evaluation procedure

The field performance evaluation of modified wheat straw chopper has been carried out in the fields of Chakra Farms of University of Agriculture, Faisalabad. The instruments used for the performance analysis includes measuring tap, ruler, vernier caliper, weight balance, stop watch, ranging rods, graduated cylinder, oven, thermometer etc.The independent variable that effect the performance of wheat straw chopper were taken as 1) three different wheat varieties V_1 (Sehar-2006), V_2(Lasani) and V_3(Faisalabad-2008), 2) two levels of tractor forward speeds S_1(1.77) and S_2(2.42), 3) two levels of moisture contents M_1(moisture at the same day of combining), M_2(moisture after one day of combining)as shown in Table 4. The dependent variables for performance assessment of wheat straw chopper weremeasured as straw yield, straw size, fuel consumption and machine efficiency. The experiment was consisting of Factorial Completely Randomized Design to analyze the effect of independent variables on dependent variables. The experiment was replicated thrice. The data collected was analyzed at 5% probability level using PROC/GLM (General Linear Model) procedures of SAS institute (SAS, 2009).

Table 4 Factors involving in the experiment

Factors	Levels	Description
Wheat varieties	V_1	Sehar-2006
	V_2	Lasani
	V_3	Faisalabad-2008
Tractor forward speed (km/h)	S_1	1.77 at 1st low gear
	S_2	2.42 at 1st high gear
Moisture level (%)	M_1	On the same day of combining
	M_2	After one day of combining
Replications	R_1	First replication
	R_2	Second replication
	R_3	Third replication

3 Result and discussion

The data collected during machine operation in the fields was statistically analyzed and the results are discussed as follows:

3.1 Effect ofwheat varieties on machine efficiency

The replicated average wheat straw chopper efficiency for wheat varieties V_1, $V_2$and $V_3$was found to be 67.76%, 68.66%and 68.01% respectively at M_1 and 67.64%, 68.21% and 67.5% at M_2. The overall average wheat straw chopper efficiency both at M_1 and $M_2$was calculated to be68.14% and 67.78% respectively. The statistically analyzed results showed that machine efficiency was not significantlydifferent for all the wheat varieties V_1 (Sehar), V_2 (Lasani) and V_3(Faisalabad-2008) as shown in Figure 5a. However, the higher choppingefficiency was found for V_2at M_1that isbeing due to the low straw yield.

3.2 Effect of wheat varieties on what straw size

The average straw size for all the wheat varieties were found to be non-significant when comparing at the same moisture level which seems to be due to the use of the same chopper for all the wheat varieties. However, the straw size of all the wheat varieties at moisture level M_2 was significantly different with all the wheat varieties at moisture level M_1 (Figure 5b). The average wheat straw size for different replications for V_1, V_2 andV_3 was found to be2.05, 1.98 and 2.01 cm at M_1 and 2.75, 2.72 and 2.81 cm at M_2 respectively.

3.3Effect of wheat varieties on what straw yield

The replicated average straw yield for wheat variety V_1, V_2, and V_3 was measured to be 1461.88, 1150.68 and 1257.90 kg/haat M_1 and 1389.25, 1085.32, 1101 kg/ha at M_2respectively. The statistically analyzed results showed that the wheat straw yield was significantly different for all the wheat varieties (Figure 5c). The wheat straw yield was significantly greater for wheat variety V_1 (Sehar) for both the moisture levels as compared to V_2 (Lasani) and V_3 (Faisalabad-2008).This is certainly due to the greater plant height and population density of V_1respect to V_2 and V_3. The maximum wheat straw yield was measured for variety V1 (Sehar) both at M_1 and M_2.Therefore, it can be concluded that V_1 could be used to get higher wheat straw yield.

3.4 Effect of wheat varieties on fuel consumption

The replicated average fuel consumption for V_1, $V_2$and $V_3$was measured to be 9.93, 9.56, and 8.86 L/ha at M_1 and 9.64, 9.25 and 9.01L/ha at M_2respectively.The statistically analyzed results showed that fuel consumption of the tractor was not significantly different for all thewheat varieties (Figure 5d). The average fuel consumption for all the wheat varieties and both moisture levels werefound to be 9.38 l/ha. The maximum fuel consumption was measured for V_1 as compared to V_2 and V_3. This is certainly due to higher crop height and wheat straw yield required more power to work and resulting higher fuel consumption.

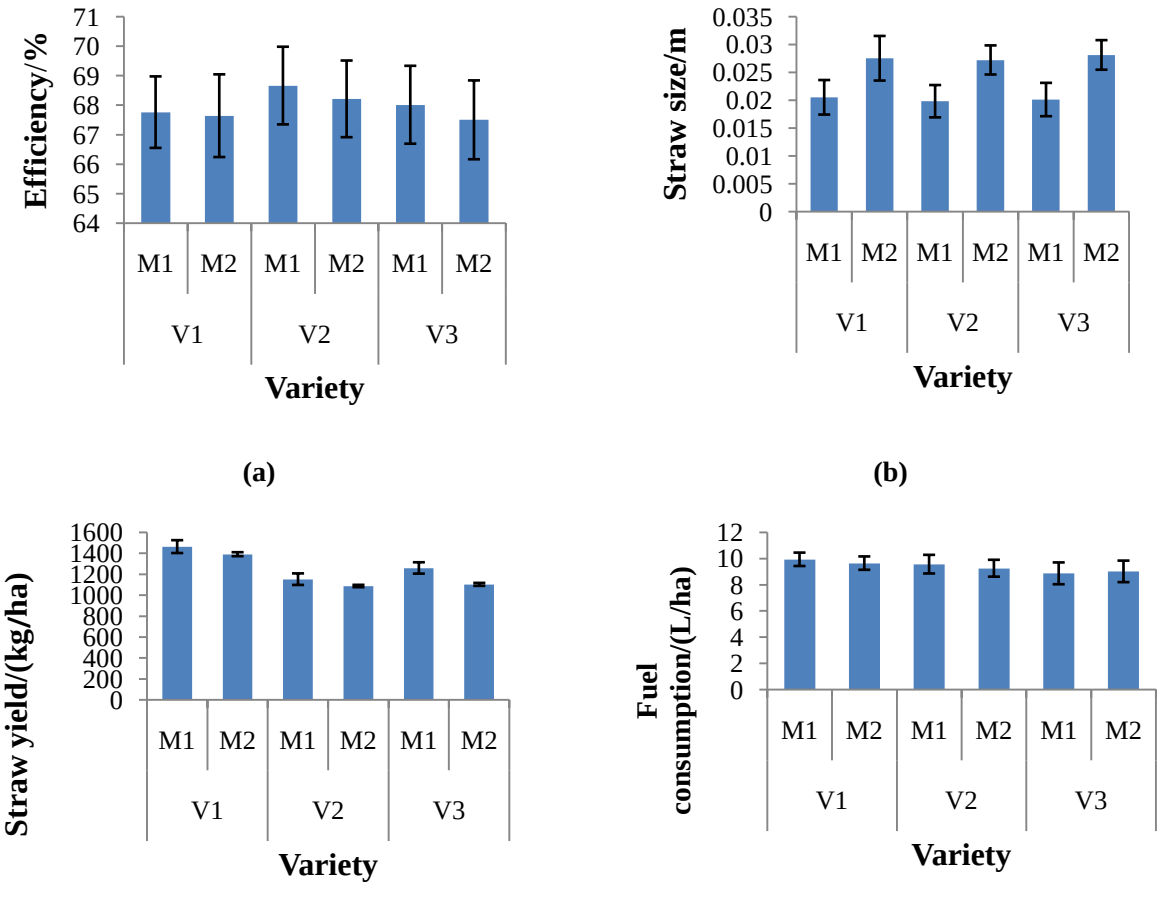


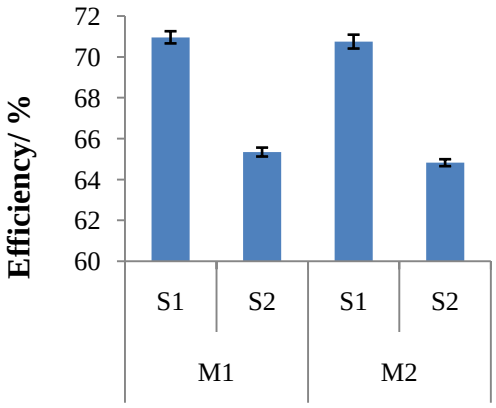
Figure 5 Effect of wheat varieties on chopper efficiency, straw size, straw yield and fuel consumption

3.5 Effect of moisturelevelson wheat straw chopper efficiency

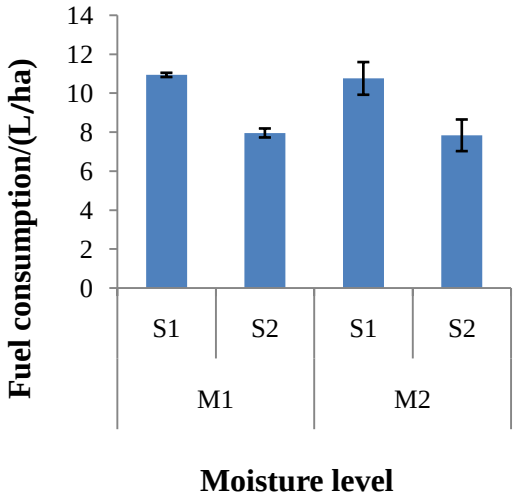
The effect of moisture level on wheat straw chopper efficiency was not significantly different when comparing for same tractor forward speed (Figure 6a). However, the effect of moisture level on machine efficiency was significantly different for both tractor forward speeds.The higher wheat straw chopper efficiency was achieved at $S_1$for both the moisture levels which showthat lower tractor forward speed results higher wheat straw chopper efficiency.The maximum wheat straw chopper efficiency was measured to be 70.95% at S_1 and M_1.

3.6 Effect of moisture contents on fuel consumption

The replicated average fuel consumption for M_1 and M_2 was measured to be 10.94 and 10.76 L/haat S_1 and 7.96 and 7.84 L/ha at S_2. Therefore, it is clear from Figure 6(b) that fuel consumption of the wheat straw chopper is not significantly different while operating the wheat straw chopper at M_1 and $M_2$for same tractor speed.However, the fuel consumption is significantly different for tractor forward speeds S_1 and S_2 both at M_1 and M_2.



(a)



(b)

Figure 6 Effect of moisture contents on chopper efficiency and fuel consumption

3.7Effect of tractor forward speed on machine efficiency

The replicated average wheat straw chopper efficiency for wheat varieties V_1, $V_2$and $V_3$was found to be70.6%, 71.29% and 70.64% at S_1 and 64.79%, 65.58% and 64.87% at S_2respectively. The statistically analyzed results showed that significantly higher wheat straw yield was obtained at S_1 than S_2(Figure 7a).The higherwheat straw chopper efficiency at S_1 could be due to more machine maneuverability at low forward speed of the tractor.Therefore, tractor forward speed S_2 was considered as less effective and unsatisfied speed for the wheat straw chopper.

3.8Effect of tractor forward speed on straw size

The replicated average wheat straw size for wheat varieties V_1, $V_2$and $V_3$was measured to be 1.63, 1.73 and 1.77cm at tractor forward speeds S_1 and 3.17, 2.96 and 3.05 cm at tractor forward speed S_2respectively.The statistically analyzed results showed that significantly lower wheat straw size was obtained for S_1as compared with S_2(Figure 7b).At lower forward speed of the chopper, more chopping time is available reducing wheat straw size than that at speed S_2.

3.9Effect of tractor forward speed on wheat straw yield

The replicated average wheat straw yield for wheat varieties V_1, $V_2$and $V_3$was measured to be1498.9, 1175.56 and 1249.48 kg/haat tractor forward speed$S_1$and 1352.23, 1060.43 and 1109.41 kg/haat S_2respectively. The statistically analyzed results showed that significantly greater wheat straw yield was obtained for tractor forward speed S_1 than S_2(Figure 7c).The reason could be that during the operation of the wheat straw chopper at lower forward speed (S_1)picked up more crop residue left in the rear side of the combine harvested resulting higher wheat straw yield.

3.10Effect of tractor forward speed on fuel consumption

The replicated average fuel consumption for wheat varieties V_1, $V_2$and $V_3$was measured to be10.89, 10.90 and 10.76 L/ha at tractor forward speed S_1 and 8.68, 7.92 and 7.11 L/ha at S_2respectively.The statistically analyzed results showed that significantly greater fuel consumption was obtained at tractor forward speed S_1 than S_2(Figure 7d).This shows that higher tractor forward speeds results higher effective field capacity resulting higher machine efficiency and lower fuel consumption.

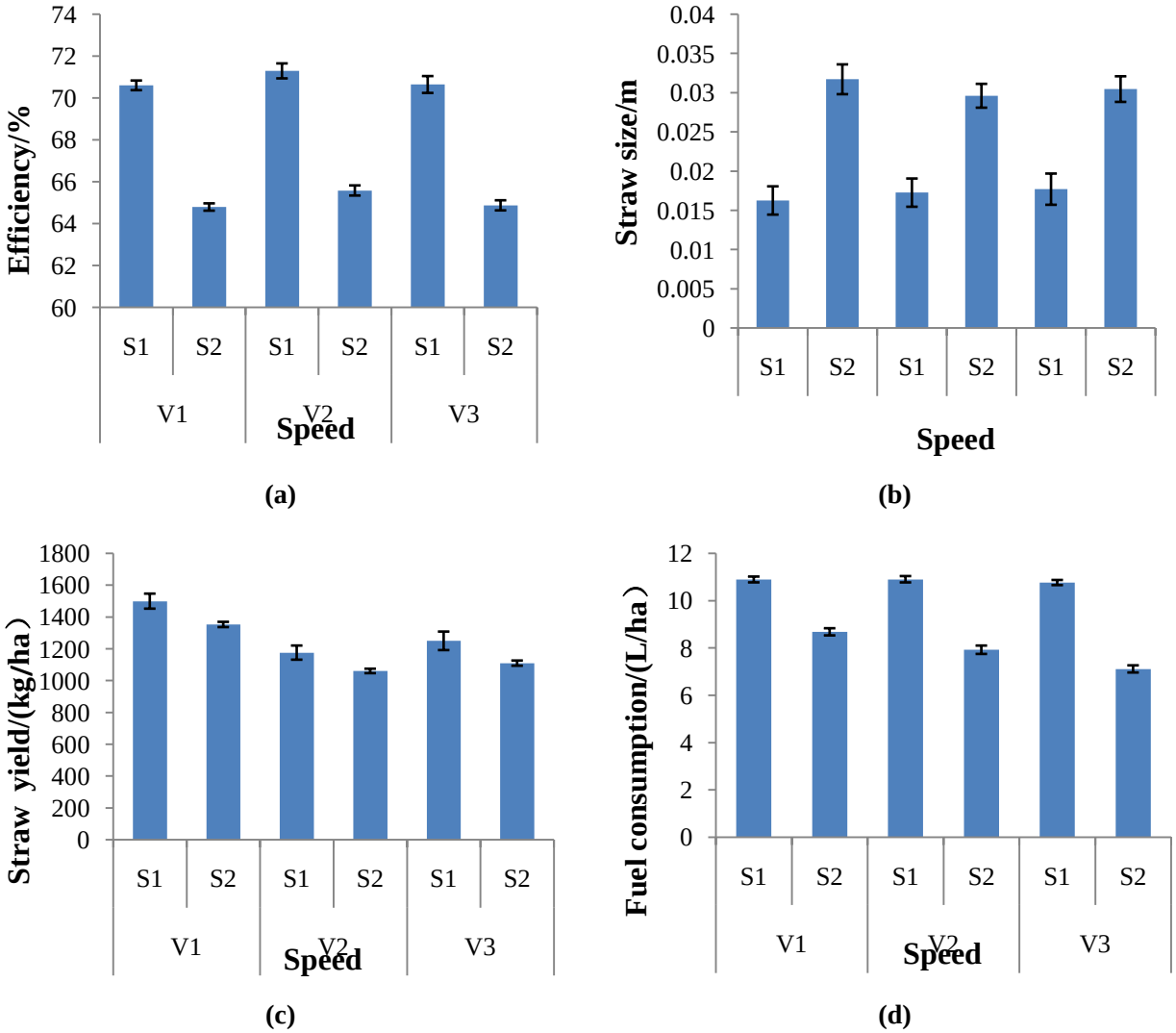


Figure 7 Effect of tractor forward speed on chopper efficiency, straw size, straw yield and fuel consumption

3.11Break even analysis

Break even analysis focuses upon the profitability of an organization. The specific concern inthe breakeven analysis is identifying the level of operation that would result in a zero profit.At breakeven point there is no net loss or gain.Breakeven analysis is an important tool when launching new products. The breakeven point is a useful reference point in such a way that it indicates the level of

operation at which total revenue equals total cost.The cost analysis of wheat straw chopper was carried out. The breakeven point of the wheat straw chopper occurred at 225 hours of the use (Figure 8). It shows that farmers can easily cross the breakeven point and earn more profit.

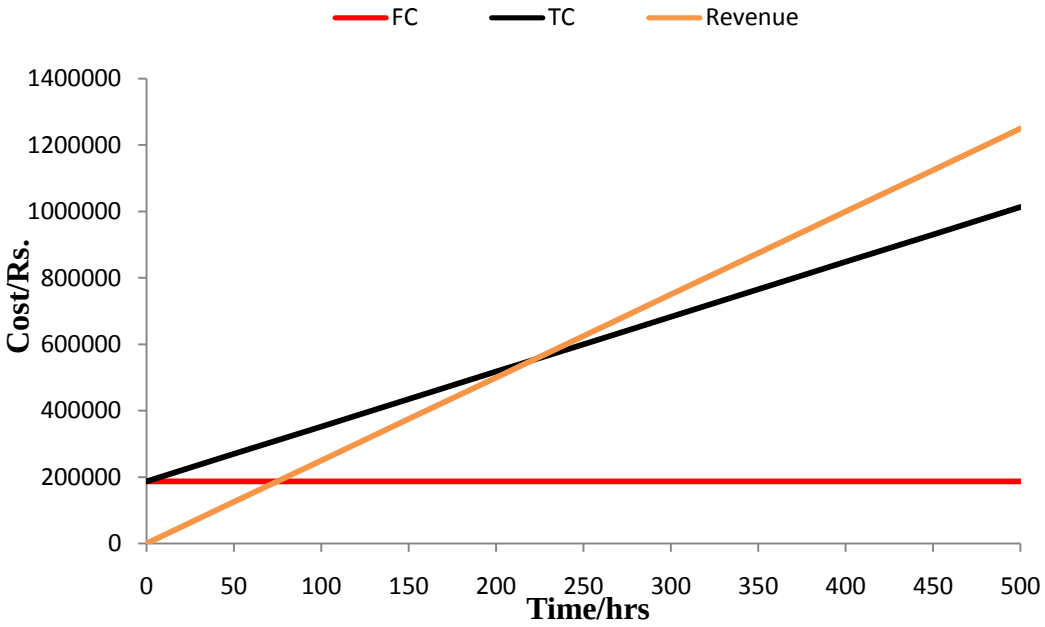


Figure 8 Breakeven analysis of the wheat straw chopper

4 Conclusions

The straw management in combine harvested fields is a major problem for farmers. Normally, the residual wheat straw is burnt in the field which results lossesof 80% Nitrogen, 25% Phosphors, 21% K and 4% to 60% Sulphur.Locally made conventional wheat straw choppers used for collecting combine harvested residue are heavier in weight resulting lower chopper efficiency and higher fuel consumption. A wheat straw chopper has been modified using locally available materials making it light weight and more efficient. The performance evaluation of wheat straw chopper has been carried out for three wheat varieties, two different tractor forward speeds and two levels of moisture contents. The data was collected under actual field conditions and the results have been statistically analyzed using statistical tool. The results showed that different wheat straw yield was obtained for different tractor forward speeds. The wheat straw yield was measured to be 1425, 1118 and 1179 kg/ha at tractor forward speeds V_1, V_2 and V_3 respectively. Similarly, the results of moisture effect on wheat straw yield were also significant resulting higher wheat straw yield at moisture content level M_1.The wheat variety V1 has shown higher wheat straw yield and chopper efficiency at tractor forward speed S_1(1.77 km/h).The maximum wheat straw chopper efficiency was measured to be 70.95% at S_1 and M_1..The results also shows that fuel consumption of wheat straw chopper is not significantly different while operating the wheat straw chopper at M_1 and $M_2$for same tractor speed.However, the fuel consumption is significantly different for tractor forward speeds S_1 and S_2 both at M_1 and M_2. The average fuel consumption for wheat varieties V_1, $V_2$and $V_3$was measured to be10.89, 10.90 and 10.76 L/haat tractor forward speed S_1 and 8.68, 7.92 and 7.11 L/ha at S_2 respectively. Therefore, it could be concluded that higher tractor forward speeds results higher effective field capacity resulting higher machine efficiency and lower fuel consumption. The average fuel consumption both for S_1 and $S_2$was found to be 9.38 L/ha.The cost analysis of wheat straw chopper resulted that the cost of first hour of use of machine was found to

be Rs. 75.43 while the breakeven point of the wheat straw chopper occurred at 225 hours of the use. It shows that farmers can easily cross the breakeven point and could earn more profit.

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